Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

TECHNICAL REPORT Investigations and Monitoring Group

An investigation into the southward migration of the Waimakariri River mouth

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Tony Boyle

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PO Box 345
Christchurch 8140
Phone (03) 365 3828
Fax (03) 365 3194

75 Church Street
PO Box 550
Timaru 7940
Phone (03) 687 7800
Fax (03) 687 7808

Website: www.ecan.govt.nz
Customer Services Phone 0800 324 636

Executive summary

The Waimakariri River is currently migrating rapidly southwards. This report examines matters pertaining to this and recommends for reasons set out no action to halt this migration for the short to medium term.

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1 Project brief

The Waimakariri River is migrating rapidly southwards. The brief for this report was to investigate all matters pertaining to this to aid decision making related to Canterbury Regional Council's response.

Photo 1-1: The long northern spit with the mouth to the right

Photo 1-2: **The eroding southern spit (currently 20 m/year)**

Photo 1-3: **The rapidly eroding southern spit (2010-2011 – 20 m/year - up from 1 m/year previously)**

2 Context

The context is well stated in the NIWA report: Sedimentation in the Styx River Catchment and Brooklands Lagoon, D. Murray Hicks and Maurice Duncan, December, 1993, which is reproduced below.

2.1 Introduction: a dynamic setting

Brooklands Lagoon owes its origin principally to the interaction of the large, powerful and sediment-laden Waimakariri River and a predominantly southerly longshore drift along the prograding Pegasus Bay coast. Superimposed on these controls are the effects of sand blowouts and inflows from the Styx River. Man has also had an influence in stabilising the Waimakariri mouth and sand-dune blowouts.

Left to its own devices the Waimakariri River mouth would likely migrate from somewhere just north of its current position to the south end of Brooklands Lagoon. There would be a cycle of the river breaking through the spit near the location of the current mouth during a large flood with the mouth moving southwards again under the influence of the longshore drift and the lagoon deepening to accommodate the flow as the mouth moved south. ***Note: The deepening would be of the order of 2m.*** *When a breakout occurred the lagoon would be left as a deep backwater which would quickly infill with sediment spilled from the river, blown over the sand spit by the prevailing north easterly wind, or washed over by storm waves. Even with the present lagoon configuration the Styx River likely exerts only a small influence on lagoon sedimentation processes mainly in reworking the lagoon sediments towards the mouth and then generally only when the tide is low. The supply of sediment to the lagoon from the Styx catchment is small compared to the amount that circulates in and out with Waimakariri water.*

2.2 Recent history

The lower reaches of the Waimakariri River and the Brooklands Lagoon area have changed dramatically in the last 140 years through a combination of natural events and river control works. Maps and photographs show the changes well. An 1865 map shows the lagoon with a very wide mouth between spits built from north and south. A map dated 1880 shows only a short spit attached at the north and no lagoon at all. A further map dated 1928 shows a configuration similar to that of 1865. ***These maps are of interest to this study in that with these configurations the flood levels would be very similar to those which occur with a centred mouth.***

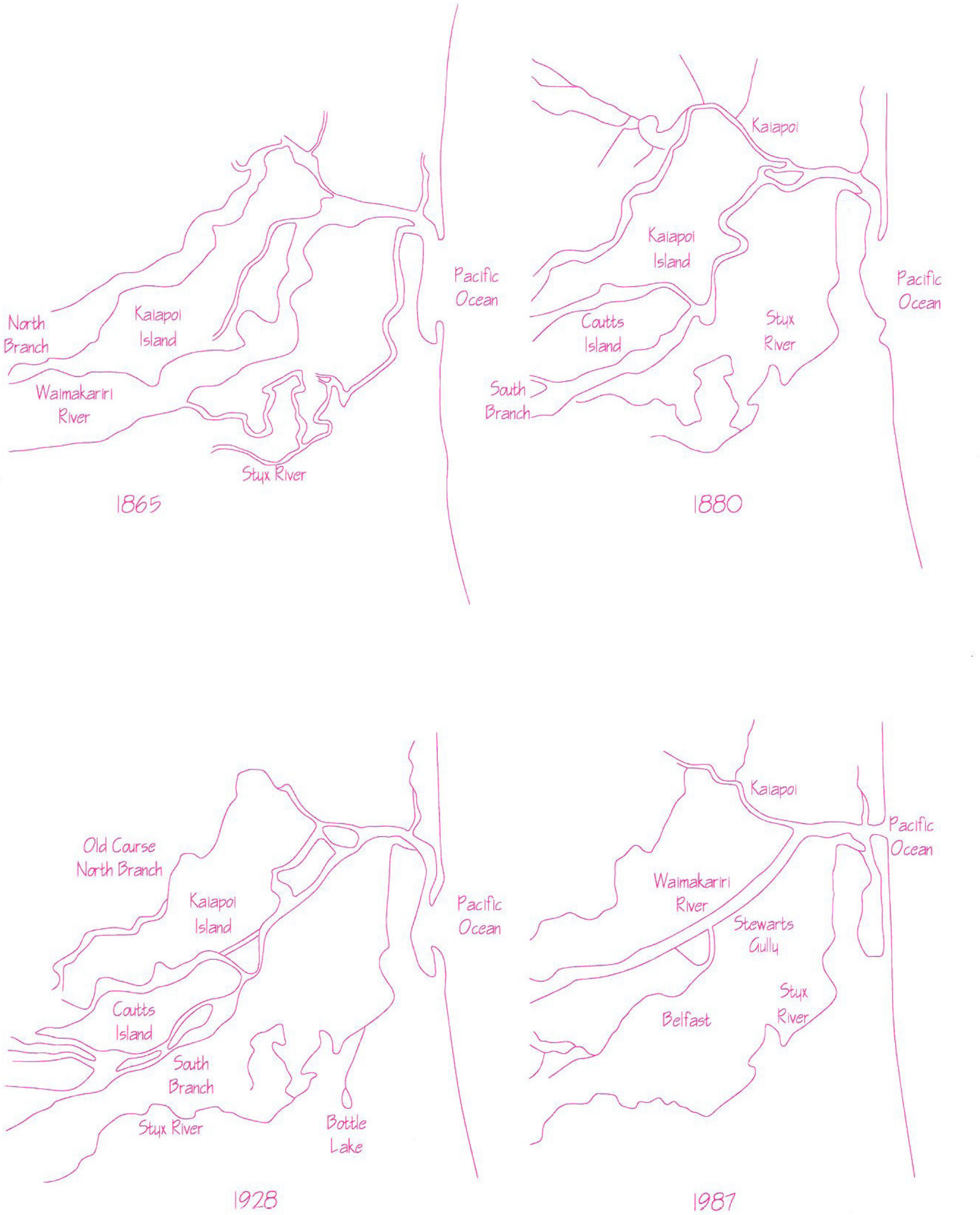

Figure 2-1: Waimakariri River mouth configurations: 1865, 1880, 1928 and 1987

In 1930 in an attempt to lessen the risk of flooding engineers made a cut in the sand hills to create a new direct course to the sea to the south of the current opening. The river continued to use the natural mouth until 1940 when it shifted 3 kilometres north to its current position during a flood. Rock bank protection on the north bank of the river opposite Brooklands Lagoon probably encourages the mouth to maintain its present position.

Photographs from 1940 show the current spit area as a broad expanse of water and shifting sand bars with little vegetation on the spit and lagoon openings at the centre and the north end. A 1983 aerial photograph shows dramatic changes with vegetation on the spit and north bank of the Waimakariri. ***Note: Following the big wind of the 70's the dense plantation of pine trees self seeded.*** *The present vegetation coverage is more extensive still with large trees covering more of the spit than is evident in the 1983 photo. Thus what was a desolate area of shifting sand bars and lagoon mouths before 1940 has now transformed into a relatively stable vegetated environment.*

Although the southern end of the lagoon was silting up even in the 1930's the lagoon appears to have filled substantially since the 1940's both with silt and sand from the Waimakariri River and sand blown and washed from the open coast.

In 1978 storms widened a narrow low point in the spit at the site of the old (1930's) river mouth (3km south of the present river mouth and the location of one of the mouths modelled as part of these investigations) and over the space of a few weeks a 250 metre wide gap appeared in the dunes. Sand flooded into the lagoon on the high tides with the prevailing north-easterly wind. The foredune here has since rebuilt with the help of fencing.

2.3 Sedimentation rates: past and future

Considerable deposition occurred between 1932 and 1969. Most of this deposition occurred soon after the change in the position of the Waimakariri River mouth in 1940. Since 1969 the changes have been relatively minor. The bed of the main channel has risen by 2 m.

Peter Cooper in his report on the lagoon adds more valuable information.

2.4 Brooklands Lagoon – past, present and future

Brooklands Lagoon is at the mouth of the Waimakariri River (and its 3652 km^2 catchment) and strictly speaking is an estuary rather than a lagoon because of its semi-enclosed tidal nature. The lagoon is approximately 4.5 km long and varies in width between 250 m and 750 m. At low tide there are extensive areas of mud flat with water confined to a main channel that snakes its way south along three quarters of the lagoon's length. It is a wetland of national importance for both its vegetation and bird life. There are extensive areas of salt marsh vegetation around the edges of the lagoon and on the islands in the southern half. It is one of the least modified coastal wetlands on the east coast of the South Island.

Recreationally it is a valuable resource especially so because of its close proximity to Christchurch – just a quarter of an hours drive to the south. Fishing for flounders, salmon and whitebait in season is important. Water skiing, jet skiing, kayaking and sailing are popular. More passive activities like bird watching and walking occur around the lagoon side tracks.

The ever-enlarging settlements of Spencerville in the south and Brooklands at the north-west end increase the human pressure on the area. Subdivisions are continuing to be developed and the latest, Seafield Lagoon, is adjacent to the salt marsh at Brooklands.

The lagoon is a joint management area between the Christchurch City Council (CCC), the Department of Conservation (DoC), Environment Canterbury (ECan) and Fish and Game (F&G), with each agency having responsibility for various land activity and wildlife issues. CCC has title to most of the dry land around the edge, mostly in reserves. DoC manages the wildlife and F&G manages the game birds, *salmon and trout. ECan has some reserve land and looks after the watersports with boating regulations.*

Brooklands Lagoon is infilling with sediment. Concerns exist amongst nearby residents and the other user groups about the impact this infilling will have on the lagoon, the recreational uses and the changing flood hazard.

2.5 Previous research

A review was conducted of previous research on the sediments and bathymetry of the lagoon as a first step.

The lagoon has been surveyed across 13 lines on at least four occasions. All 13 lines were surveyed in 1931/2, 1968/9, 1976/7 and very recently in 2007/8.

In 1968 interested residents of lower Styx and Brooklands drew to the attention of the Drainage and Catchment Boards the fact that there appeared to have been a considerable building up of the bed of the Brooklands Lagoon over many years and this could have been a contributing factor in their flooding problems up-stream. The subsequent 1968/9 resurvey indicated that considerable aggradation had occurred since 1931, particularly in the main channels.

Brooklands Lagoon has undergone considerable change in recent history. Following the outlet of the Waimakariri River shifting north to its present position in the 1940's, the lagoon changed from being an active part of the lower river course to a tidal backwater. Hicks and Duncan (1993) reported sedimentation rates in the order of 30 mm yr^{-1} as the old channel filled in over the 1932 to 1969 period. Gradual infilling from the southern end was noted and some localised scouring was found near the Waimakariri River end in the north. Sedimentation rates were predicted to continue at around a few millimetres per year and be most noticeable in the southern half of the lagoon.

2.6 Historical matters

Maori settlements were well established when the first Europeans arrived, the extensive coastal swamp areas providing plentiful food. A seasonal fishing camp was located beside the lagoon. In November of 1850 Fox painted a kainga (an unfortified Maori settlement) near the present town of Kaiapoi. The early European settlers relied on the local Maori for transport across the rivers and lagoons all along this stretch of coast. The importance of the Waimakariri mouth as a food gathering source continued up until the 1880's when game fishing legislation banned the taking of game fish from the river making it difficult to fish for non-game species. More recently pollution and silting have seriously affected the use of the Waimakariri River by local Maori who now deem it culturally unsuitable for food collection.

In 1849 Alfred Rhodes started using the river mouth and up the north branch of the Waimakariri River as a port and by the early 1850's up to one hundred small trading vessels regularly called in. In the early 1850's European settlers divided the area around this part of Canterbury into large pastoral runs. Scotsman George Leach owned the large block that gave its name to Brooklands Lagoon. Overgrazing by stock and rabbits exposed the sandy soils allowing the sand to blow inland. The earliest maps of the area date from the 1850's. These show the lagoon having a long spit on both the north and south sides of the river mouth.

Charles Torlesse undertook a coastal survey in 1857. He reported a mouth one hundred yards wide that was liable to wander as much as a quarter of a mile north or south of its true course. With the rapid development of the port (wharves, store, sheds and swing bridges built at Kaiapoi) there was a need for some navigation aids for shipping. The first attempts at this in 1857 consisted of "two baskets slung from tall poles so planted on the spit and sand hills beyond that vessels could not take the entrance until the baskets had been brought into line." The shifting opening was generally two kilometres south of its present position. Many ships went aground on sandbars in the channel and on the spits north and south after missing the entrance.

Higher up in the Waimakariri River catchment forests and tussocklands were being cleared, burned and overgrazed. Swamps were recognised for their rich agricultural potential and drained. Typically in New Zealand this clearing process increased river flows by 20 to 50%. Floods were more frequent and had higher peaks and more sediment was being carried down to the coast.

In the 1860's the north and south branches of the Waimakariri had a large island between them. Kaiapoi Island was approximately eleven by five kilometres of very fertile soil. Floods in 1858 (Dudding's ferry was carried out to sea; floodwaters ran through Christchurch), 1865 (Christmas Day) and 1868 (the 'greatest of them all'), where the floodwaters flowed again down through Christchurch, there was three to four feet of water in the Post Office in Market Square and the Worcester Street bridge was fixed by rope to prevent it being washed away all highlighted the need to protect Christchurch and Kaiapoi. In 1868 a 'new channel' was cut across Kaiapoi Island by farmers by hand to where the existing bridges are. This was a big success as it stopped flooding of their farms although an unexpectedly large amount of valuable island farmland was lost. The north branch flowing to Kaiapoi quickly choked up with sediment.

The year 1866 saw the 17 ton cutter "Iris" become the first wreck on the bar (there were seven more later that year). The first harbourmaster was appointed. The volume of freight being shipped through the port was substantial – in 1870 there were, amongst other things, 5,000 bales of wool, 334,000 bushels of grain and 10,000 eggs. The Waimakariri Harbour Board was constituted and dredging began on the north branch to remove the silt that was hindering shipping.

In 1880 flood waters cut a new river course down Stewart's Gully through Stewart's farm. This was the second of four stages in the river straightening through its lower course. Another flood in 1885 cleared out the northern channel sufficiently for the Harbour Board to sell their dredge. Its replacement (the Hinemoa) was soon needed, but was lost at sea after being carried down the river in another flood.

An indication of the scale of shipping over the bar and up the river was given by the arrival of a new steamer built in Dublin for the Kaiapoi Shipping and Trading Company. The 'Kaiapoi' was capable of ten knots and could carry 580 tons of cargo, reflecting the owners confidence in the port. Unfortunately with WW1 larger shipping ceased and the port no longer thrived. The third dredge, commissioned in 1907, was no longer needed. This dredge was sold after a major flood in 1923 cut a new channel to the sea closer to Kairaki. The Otira tunnel completion spelt the end of the West Coast shipping trade.

After WW1 various attempts were made to re-establish a new Waimakariri Harbour Board and grand plans included a training wall to stabilise the bar. Financial constraints prevented this from happening. In 1921 the township of Brooklands was divided up and a roading pattern laid out. The line of the main esplanade road for the town now runs close to the centre of the lagoon – the shifting of the river mouth changed much of the plan.

For many years concerns existed about shingle aggradation in the lower course of the river and the subsequent increase in flood risk to Christchurch. There was much controversy over what needed to be done. The Waimakariri River Trust was formed by another act of parliament, 'The Waimakariri Improvement Act, 1922.' Engineer F. C. Hay put forward his proposals in 1925. These were:

1. *Controlled channel No. 1, guiding the river into the south end of the lagoon.*
2. *Controlled channel No. 2, into the north end of the lagoon (but still south of today's river), and:*
3. *Possibly a connecting channel of some sort.*

Controlled channel No. 2 was chosen.

River experts from Europe and North America were commissioned to provide advice on what should be done. It was agreed that the river needed to be channelled and straightened as it flowed out to sea in order to carry shingle and sand more efficiently. A map from the same report shows the shape of the lagoon in 1928 and large spits can be seen both north and south of the entrance.

In 1930 the 'new cut' was made joining the 'New Channel' of 1868 and straightening the river above the bridges. This was called Wrights Cut. This and the new channel down Stewarts Gully left only the lower section of Hay's proposal to be completed.

Hay wanted to allow a direct run out to sea rather than through the channel behind the spit. By 1931 despite a strike by hundreds of unemployed men working on the scheme the lower cut was complete. 2.8 kilometres had been excavated along with a 500 metre side cut to bring the Kaiapoi River over to join it. Sandhills were dug away on the north spit and over 1000 ten-ton concrete blocks were set in place to stabilise the new spit after the change. Maps held by Environment Canterbury from the 1920's and 30's show the excavation works and location of the concrete blocks. Aerial photographs from today still clearly show the channel works. A grand opening of the lower cut held for invited dignataries was not a success – the river declined to cooperate because of the low flow and tidal conditions at the time. The Waimakariri carried on its course as usual. It is worth noting that prior to this floods in 1926 washed away five cottages from Kairaki and ten years later another four baches were swept out to sea.

The southern end of Brooklands Lagoon began silting up in the 1930's. Mudflats disappeard and were replaced by reedbeds. In 1934 the Styx River tidal gates were installed (to be replaced in 1981).

Until 1940 the river mouth opened to the sea about two thirds of the way along the spit. The 1931 engineering works met no success but in 1940 a 132,000 cusec flood shifted the mouth about three kilometres north (helped along by some timely excavation) to its present position at Kairaki. A rock bank has been built on the north side of the river at Kairaki and this helps the river mouth stay where it is. ***(Note: this bank probably arrests northern migration meaning that for the period of natural northern migration the river would hold a steady course straight out to sea which has been the case until recently).***

Substantial infilling of the old river channel down the lagoon followed. The North Canterbury Catchment Board took over from the River Trust in 1946 and in 1952 the Christchurch Drainage Board took over the management of the Styx catchment starting a programme of drain improvement and dredging.

The long southern spit that now exists has been planted with marram grass and pine trees to try and stabilise the shifting sand dunes. ***Note: Local opinion is that the spit self seeded following the major wind storm during the 1970's.*** *In the early 1970's the spit consisted of three rows of tall sand dunes. Between 1973 and 1977 a series of storms and high seas washed away a 15 – 18 metre wide strip of the spit's dune system. These storms were the worst in terms of beach impacts on record for Pegasus Bay.*

In 1978 storms widened a narrow gully at the site of an old river mouth ***(this is the site of one of the mouths (3km to the south) in the modelling carried out as part of these investigations)*** *and a 250 metre wide gap opened in just a few weeks. Sand flooded into the lagoon with the high tides and prevailing wind. Rangers from Spencer Park built wind netting fences which quickly stabilised the sand and marram grass was planted. Since then two kilometres of fencing has been incorporated in protecting the dunes in this area.*

The river flood protection works (stopbanks etcetera) are engineered to cope with a one in a five hundred year event. The largest river flood since reliable records began was in 1957 measuring 3990 $m^3.s^{-1}$*. Aggradation in the lower reaches can lessen the effective protection provided by the stopbanks.*

The position with respect to Waimakariri bed levels was recently investigated in depth. The Executive Summary of the investigation report is reproduced below.

> *"This report explores the history of flooding and human responses to that flooding with particular emphasis on sedimentation of the Waimakariri River from the Lower Gorge to the coast.*
>
> *The changes in mean berm, mean channel (fairway) and channel invert (lowest) level between 1960 and 2008 are recorded and analysed.*
>
> *By comparing a variety of indicators recommended bed levels are derived.*

The recommended bed levels are intended to:

- *Maintain a flood capacity to meet scheme objectives.*
- *Limit berm edge heights to enable erosion risk to be managed and to protect existing infrastructure such as bridges and intakes.*
- *Reduce the variability of mean bed level slope without introducing large changes in slope to assist with river bed stability and consistency of bedload transport capacity.*
- *Maintain a consistency of flood capacity over the length of the scheme.*

Allowing extraction of gravel and sediment down to proposed minimum bed levels would yield about 7 million cubic metres (as at the most recent survey).

Downstream of Crossbank some of the proposed minimum bed levels are higher than the minimum levels already specified in existing gravel extraction consents.

To avoid adverse cumulative effects these consents need to be considered on an individual basis for review."

3 Hydraulic modelling

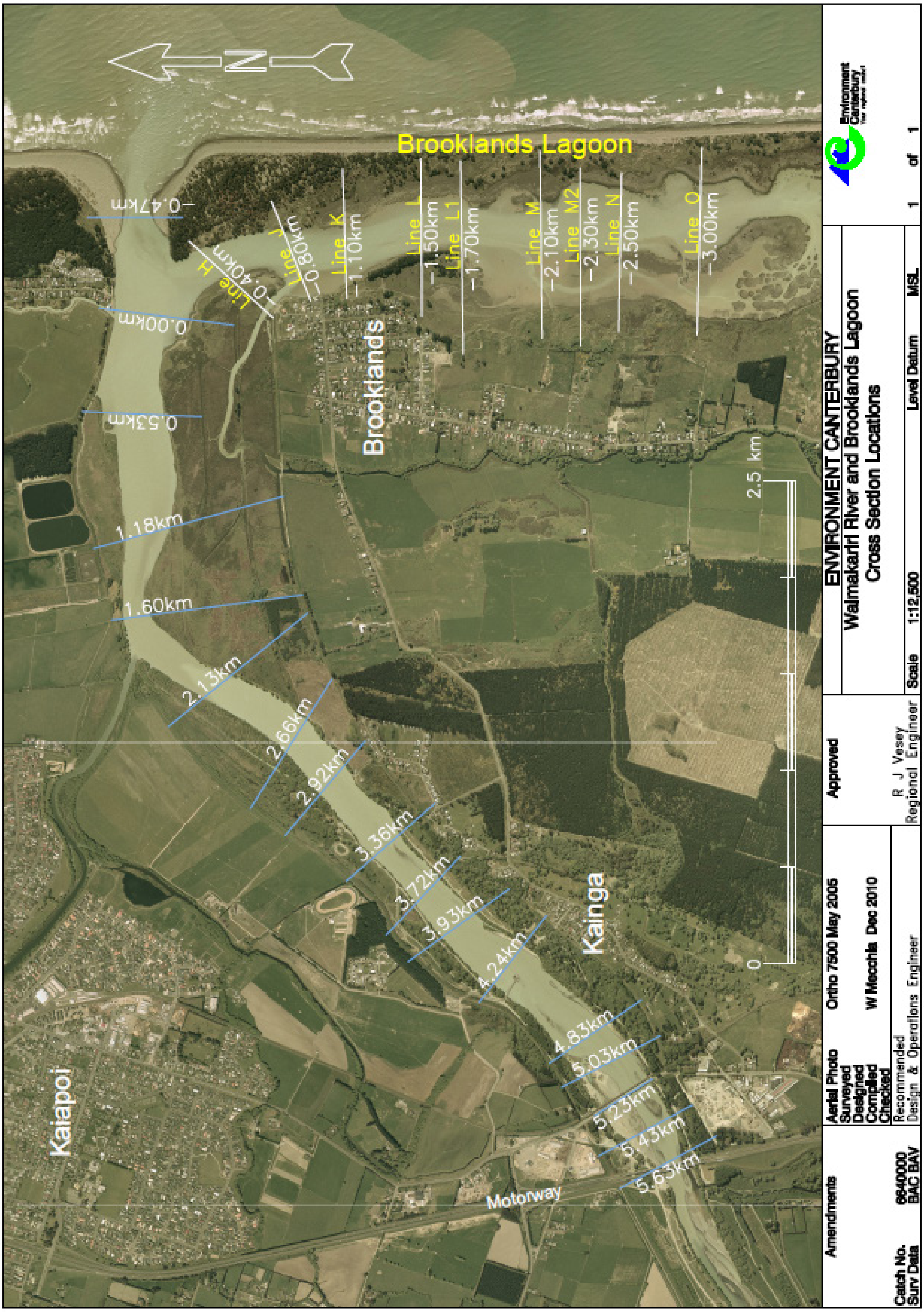

Figure 3-1: Waimakariri River and Brooklands Lagoon cross section locations

The Waimakariri River was recently modelled utilising the latest surveyed cross sections. As part of this investigation the Brooklands Lagoon Sections were added into the model mouths 1.5 and 3 kilometres to the south of the current mouth. The results of the modelling exercise are detailed below along with the calculated centred mouth levels.

Table 3-1: Calculated flood levels

X/Section	Mike 11 Distance	Centred Mouth	Mouth 1.5km south, 1930's sections	Mouth 3km south, 1930's sections
-3000	103000			1.70
-2500	102500			2.26
-2300	102300			2.47
-2100	102100			2.67
-1700	101700			2.95
-1500	101500		1.70	2.98
-1100	101100		2.04	3.00
-800	100800		2.29	3.08
-400	100400		2.53	3.19
0.00	100000	1.7	2.75	3.30
0.530	99470	2.2	2.91	3.39
1.180	98820	2.8	3.28	3.67
1.600	98400	2.9	3.33	3.71
2.130	97870	3.2	3.58	3.90
2.570	97340	3.5	3.77	4.04
2.920	97080	3.6	3.81	4.06
3.360	96640	4.0	4.19	4.37
3.720	96280	4.6	4.71	4.84
3.930	96070	4.9	4.96	5.07
4.240	95760	5.1	5.15	5.25
4.830	95170	5.5	5.59	5.66
5.030	94970	5.6	5.71	5.77
5.230	94770	5.7	5.75	5.80
5.430	94570	6.0	6.06	6.10

3.1 Analyses

With a very narrow opening 3 kms to the south of the existing mouth the stopbanks of the lower Waimakariri would need to be raised of the order of 1 metre (1.5 m downstream of the boat ramp) to contain flood flows. With the mouth 1.5 km south this would reduce to 400mm (900mm downstream of the boat ramp.

In point of fact, all the historical maps and photographs record very wide openings to the sea with the breaker lines on the seaward side of the bar and with the main channel on the east side of the lagoon which would mean minimal additional engineering works should be necessary. The 1930's cross sections also show the main channel on the east side of the lagoon (on the opposite side from Brooklands).

3.2 Findings

There is no apparent pressing hydraulic necessity to halt the natural southern migration of the mouth. Even at the very maximum rate of movement (20m/year) it would take a very long time to move 3kms.

The historical mechanism has involved gradual southern movement with erosion of the spit face rather than a sudden avulsion into the lagoon.

4 Recommendation

The recommendation that flows out of this investigation is to allow nature to take its course in the short to medium term. The current monitoring programmes are sufficient to review this course of action in the medium to longer term or if unforeseen situations suddenly develop.

Environment Canterbury Regional Council
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Environment Canterbury offices

Christchurch
58 Kilmore Street
PO Box 345
Christchurch 8013
P: 03 365 3828
F: 03 365 3194

Timaru
75 Church Street
PO Box 550
Timaru 7940
P: 03 687 7800
F: 03 687 7808